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# Should we estimate plant cover in percent or on ordinal scales? II – Diversity indices

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## Abstract

**Question**: We asked whether ordinal cover scales cause biases in biodiversity indices derived from vegetation plots and, if so, whether a different back-translation of ordinal categories could improve the situation. **Methods**: We took three empirical vegetation-plot datasets from different regions and habitat types with species cover estimated in percent. We applied three ordinal cover scales (13-step Londo, 7-step Braun-Blanquet and 5-step Hult-Sernander-Du Rietz) and back-transformed the resulting categories to percent (mid-point of the respective cover class). For each plot, we then calculated three diversity metrics (Shannon diversity, Shannon evenness, Simpson diversity) before and after applying the ordinal scales and using arithmetic and geometric means for back-translation. **Results**: The Hult-Sernander-Du Rietz scale led to strongly increased values for the three diversity metrics when arithmetic mid-points were applied and to strongly decreased values when geometric mid-points were applied. Likewise, for the Braun-Blanquet and Londo scales the diversity indices had a positive bias in the case of arithmetic means and negative in the case of geometric means, but the differences were much smaller and not always significant. The ranking of communities by their biodiversity metrics was severely distorted for any combination of ordinal scale, biodiversity metric and transformation, but most strongly for the Hult-Sernander-Du Rietz scale. **Conclusions**: Our study suggests that in many cases the use of ordinal scales biases diversity metrics systematically. Since biodiversity metrics are commonly used to compare communities, our finding that the ranking of communities changed considerably when an ordinal scale was applied raises concerns about commonly applied practices. It suggests that in such studies percent cover estimates should be used. For the use of legacy data with ordinal scales we did not find a clear prevalence of arithmetic or geometric back-translation and thus recommend searching for alternative approaches.

## Keywords

Braun-Blanquet scale, Hult-Sernander-Du Rietz scale, Londo scale, ordinal scale, percent estimate, plant cover, relevé, Shannon diversity, Shannon evenness, Simpson diversity, species-abundance distribution, vegetation-plot database

## Introduction

Plant cover assessment is a central methodological step in vegetation ecology, phytosociology and habitat monitoring (Dengler et al. 2008; Kent 2012; Bruelheide et al. 2019). While percent cover is considered the relevant measure, most researchers do not note percent covers directly, but one of the many ordinal cover-abundance scales instead (see reviews by Whittaker 1973; Dierschke 1994; Peet and Roberts 2013; Dengler and Dembicz 2023). The Braun-Blanquet scale with its numerous variants is the most popular among these ordinal scales, accounting for 66% of all plots in “sPlot”, currently the most comprehensive vegetation-plot database on Earth (Bruelheide et

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al. 2019). Only 15% of the plots used direct percent cover, and 19% one of the other 55 numeric or ordinal measures, including just presence-absence (Bruelheide et al. 2019).

In a recent publication we tested with simulations how the use of ordinal cover scales influences the analytical data compared to direct percent cover estimations (Dengler and Dembicz 2023). While in either case there is an estimation error in the field, which varies depending on the experience of the researcher and the complexity of the vegetation, we found that the double transformation due to the use of an ordinal scale leads to an "error inflation". Using a 7-step variant of the Braun-Blanquet scale combined with the scenario we deemed most realistic and relevant, we found that the original estimation error on average was almost doubled when entering the numerical analyses. Based on our own experience, we find direct percent estimation equally or even less time consuming than careful estimation with an ordinal scale, we thus argued against the use of ordinal scales when the intended subsequent analyses are to be based on cover values.

While in our previous paper we showed that there is a general (and avoidable) problem with ordinal scales in numerical ecology, we left it open to future research to quantify how big the resulting biases are in different types of analyses (Dengler and Dembicz 2023). One aspect that is nearly always analysed when vegetation plots are sampled, is species diversity. While there are a multitude of diversity metrics, among the most widely used are certainly species richness, Shannon diversity, Shannon evenness and Simpson diversity (van der Maarel 1997; Maurer and McGill 2011). Species richness evidently is independent from the cover estimation method. By contrast, Dengler and Dembicz (2023) argued that Shannon diversity and Shannon evenness likely will be particularly biased when an ordinal scale instead of direct percent estimation is applied, as both use the natural logarithm of the fraction $p_i$ of a species. When $\ln(p_i)$ enters the formula, it becomes relevant whether the cover was 0.1% or 0.001%, which is unified by all ordinal scales.

Here we thus used empirical data with direct percent estimation to address the following three questions with three ordinal scales for three widely used diversity metrics that are based on cover/abundance (Shannon diversity, Shannon evenness, Simpson diversity):

(1) Does the use of ordinal scales create a systematic bias in the values of these metrics?
(2) Does the use of ordinal scales change the biodiversity ranking of plots/communities based on these metrics?
(3) If biases of type (1) or (2) occur, would a back-translation from the ordinal categories to a numerical value different from the current practice improve the situation?

# Methods

We selected three datasets from different habitats and regions, where plant cover had been estimated directly in percent (Table 1). These plots were recorded by us together with a limited number of colleagues, mostly according to the EDGG methodology (Dengler et al. 2016). The surveyors were instructed to estimate the covers in percent as precisely as possible, meaning that at the lower end usually cover values down to 0.001% were used (corresponding to 1 cm$^2$ in 10 m$^2$). The raw data (with anonymised species) are provided in Suppl. material 1, while calculated biodiversity metrics, the resulting ranks as well as the changes in metric and ranks can be found in Suppl. material 2.

Data handling and statistics were done in R, version 4.4.2 (R Core Team 2024). The original cover values in percent were translated into the ordinal values of the 13-step Londo scale, 7-step Braun-Blanquet scale and the 5-step Hult-Sernander-Du Rietz scale, as three widely used ordinal scales that with their different levels of resolution are also representative for the wide variety of existing ordinal scales (e.g. Whittaker 1973; Dierschke 1994; Peet and Roberts 2013). Subsequently, we back-translated

**Table 1.** Main characteristics of the three datasets A, B and C used in this study. The dataset ID in GrassPlot is also given (Dengler et al. 2018).

| Dataset | A | B | C |
|---|---|---|---|
| Number of plots | 32 | 171 | 60 |
| Plot size (m$^2$) | 100 | 10 | 10 |
| Region (country) | 10-km circle around Preda, Grisons (Switzerland) = DarkDivNet site D95 | Inneralpine dry valleys of Switzerland | Gotland (Sweden) |
| Vegetation type | All natural and semi-natural types of the subalpine and alpine belt (forests, grasslands, tall forb communities, heathlands, snow beds, screes) | Dry grasslands (*Festuco-Brometea*, *Sedo-Scleranthetea*) | Semi-natural grasslands from dry to wet (*Koelerio-Corynephoretea*, *Sedo-Scleranthetea*, *Festuco-Brometea*, *Molinio-Arrhenatheretea*) |
| Taxa sampled | Only vascular plants | All terricolous taxa | All terricolous taxa |
| Mean species richness (min – max) | 45.7 (4–95) | 35.3 (9–59) | 34.5 (6–67) |
| Collectors | Jürgen Dengler and Iwona Dembicz | Jürgen Dengler et al. | Iwona Dembicz and Jürgen Dengler |
| Reference | Unpublished; for DarkDivNet, see Pärtel et al. (2019) | Bergauer et al. (2022) | Unpublished |
| Dataset ID in GrassPlot | – | CH_D | SE_G |

**Table 2.** Definition of the three ordinal scales used to estimate the importance of plant species in plant communities with their definitions and their proposed back-transformation into percent cover as used in our study.

| Scale | Category | Min. cover % | Max. cover % | Standard replacement in % | Alternative replacement with geometric mean in %[2] |
|---|---|---|---|---|---|
| **Londo scale** | .1 | >0 | 1 | 0.5 | 0.03 |
| (Londo 1976) | .2 | >1 | 3 | 2 | 1.73 |
| | .4 | >3 | 5 | 4 | 3.87 |
| | 1 | >5 | 15 | 10 | 8.66 |
| | 2 | >15 | 25 | 20 | 19.36 |
| | 3 | >25 | 35 | 30 | 29.58 |
| | 4 | >35 | 45 | 40 | 39.69 |
| | 5 | >45 | 55 | 50 | 49.75 |
| | 6 | >55 | 65 | 60 | 59.79 |
| | 7 | >65 | 75 | 70 | 69.82 |
| | 8 | >75 | 85 | 80 | 79.84 |
| | 9 | >85 | 95 | 90 | 89.86 |
| | 10 | >95 | 100 | 97.5 | 97.47 |
| **7-step version of the Braun-Blanquet scale[1]** | r | >0 | 0.1 | 0.1 | 0.01 |
| (Dengler and Dembicz 2023) | + | >0.1 | 1 | 0.5 | 0.32 |
| | 1 | >1 | 5 | 3 | 2.24 |
| | 2 | >5 | 25 | 15 | 11.18 |
| | 3 | >25 | 50 | 37.5 | 35.36 |
| | 4 | >50 | 75 | 62.5 | 61.24 |
| | 5 | >75 | 100 | 87.5 | 86.60 |
| **Hult-Sernander-Du Rietz scale** | 1 | >0 | 6.25 | 3.125 | 0.08 |
| (Trass and Malmer 1973) | 2 | >6.25 | 12.5 | 9.375 | 8.84 |
| | 3 | >12.5 | 25 | 18.75 | 17.68 |
| | 4 | >25 | 50 | 37.5 | 35.36 |
| | 5 | >50 | 100 | 75 | 61.24 |

[1] We present here a variant of the Braun-Blanquet scale that appears to be widely used currently albeit it does not fully match any of the four different variants proposed by Braun-Blanquet (1964). It corresponds to Tichý et al. (2020) and is similar to the version used by TURBOVEG (Hennekens and Schaminée 2001), except that there (erroneously) the replacement for category "4" is given as 68%. [2]For the replacement with the geometric mean, we assumed the smallest recorded cover value used in this study (0.001%) as the lower boundary of the smallest ordinal category.

to the arithmetic means of the cover class borders according to prevailing practice (Table 2). To test whether a different back-translation would yield other results, we additionally applied the geometric means between the class borders as an alternative and generally applicable solution (Table 2). The idea of geometric means is inspired by the fact that in species-abundance (species-cover) distributions there are normally more species with lower than with higher cover or abundance (Preston 1948; Ulrich et al. 2022). All further analyses were done separately for the traditional back-translation and the back-translation with geometric means.

We tested the following widely used alpha biodiversity metrics: Shannon diversity, Shannon evenness and Simpson diversity (van der Maarel 1997; Maurer and McGill 2011; synonyms in bracket):

- Shannon diversity (Shannon entropy): $H' = -\Sigma p_i \ln p_i$
- Shannon evenness (Pielou evenness): $E_{\text{Shannon}} = H' / \ln(S)$
- Simpson diversity (Gini-Simpson diversity): $1 - D = 1 - \Sigma p_i^2$
- With $S$ = species richness and $p_i$ = fractional cover of species $i$ (i.e. cover of species $i$ / cumulative cover of all species)

These metrics were calculated with the package 'vegan' (Oksanen et al. 2022) for the original cover values and for the values resulting from the double transformation in each of the ordinal systems. Subsequently, we tested whether the biodiversity metrics based on the ordinal scales differed from the one based on percent cover, separately for each combination of dataset and metric. We applied paired Welch $t$-tests (as the residuals showed no problematic deviation from normality, but some deviation from homoscedasticity) with Bonferroni correction as we were only interested in the comparisons with the original values, not between the ordinal scales.

Further, for each combination of diversity metric and dataset, we rank-transformed the biodiversity metric values for each of the cover estimation approaches. Subsequently, we calculated the absolute rank change for each of the ordinal scales compared to the original percent values. These absolute values were summarized for each combination of diversity metric and dataset as mean and maximum. Finally, to make the values comparable across datasets with different plot numbers, we standardized them assuming a sample size of 100. For example, an absolute rank chance of 40 in a dataset of 50 plots would receive a standardized value of 80.

# Results

We found that the traditional replacement with the arithmetic mean of the class borders led to a systematic overestimation of biodiversity metrics when ordinal cover scales are used while the alternative replacement with the geometric mean led to a systematic underestimation (Table 3; Figures 1, 2). The overestimation was statistically significant in 22 out of 27 combinations of dataset × biodiversity metric (Figure 1), while the underestimation was significant in 23 out of 27 combinations (Figure 2). On average, the amount of overestimation was higher than that of underestimation (Table 3).

**Table 3.** Mean changes in biodiversity metrics per ordinal scale and back-translation approach, averaged across the three datasets.

| Ordinal scale | Back-translation | Shannon diversity | Shannon evenness | Simpson diversity | Average |
|---|---|---|---|---|---|
| Londo | arithmetic | 0.32 | 0.09 | 0.05 | 0.16 |
| Braun-Blanquet | arithmetic | 0.05 | 0.01 | 0.01 | 0.02 |
| Hult-Sernader-Du Rietz | arithmetic | 0.96 | 0.28 | 0.12 | 0.46 |
| Londo | geometric | -0.09 | -0.03 | 0.00 | -0.04 |
| Braun-Blanquet | geometric | -0.11 | -0.03 | -0.02 | -0.05 |
| Hult-Sernader-Du Rietz | geometric | -0.67 | -0.19 | -0.15 | -0.33 |
| **Average** | **arithmetic** | **0.44** | **0.13** | **0.06** | **0.21** |
| **Average** | **geometric** | **-0.29** | **-0.08** | **-0.06** | **-0.14** |

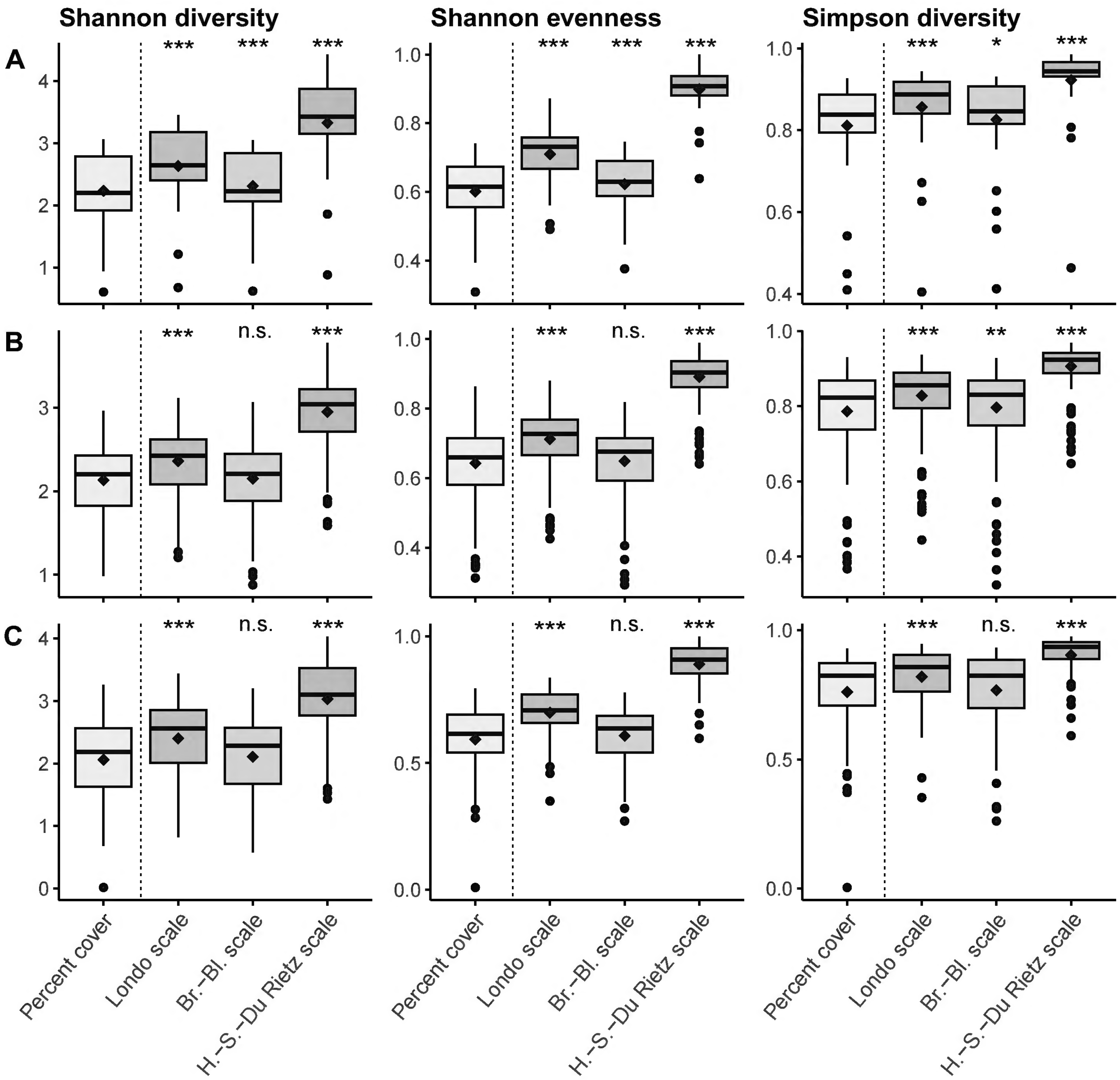


**Figure 1.** Boxplots comparing three diversity metrics across three datasets when cover values are estimated directly in percent, based on the 13-step Londo scale, a 7-step Braun-Blanquet scale, and the 5-step Hult-Sernander-Du Rietz scale. Back-translation from the ordinal scales to percent was done according to common practice with the arithmetic means of the class borders. The rows correspond to the datasets A, B and C. The asterisks indicate the Bonferroni-corrected $p$-values from paired $t$-tests of the values achieved with the ordinal scales vs. the values on the original scale.

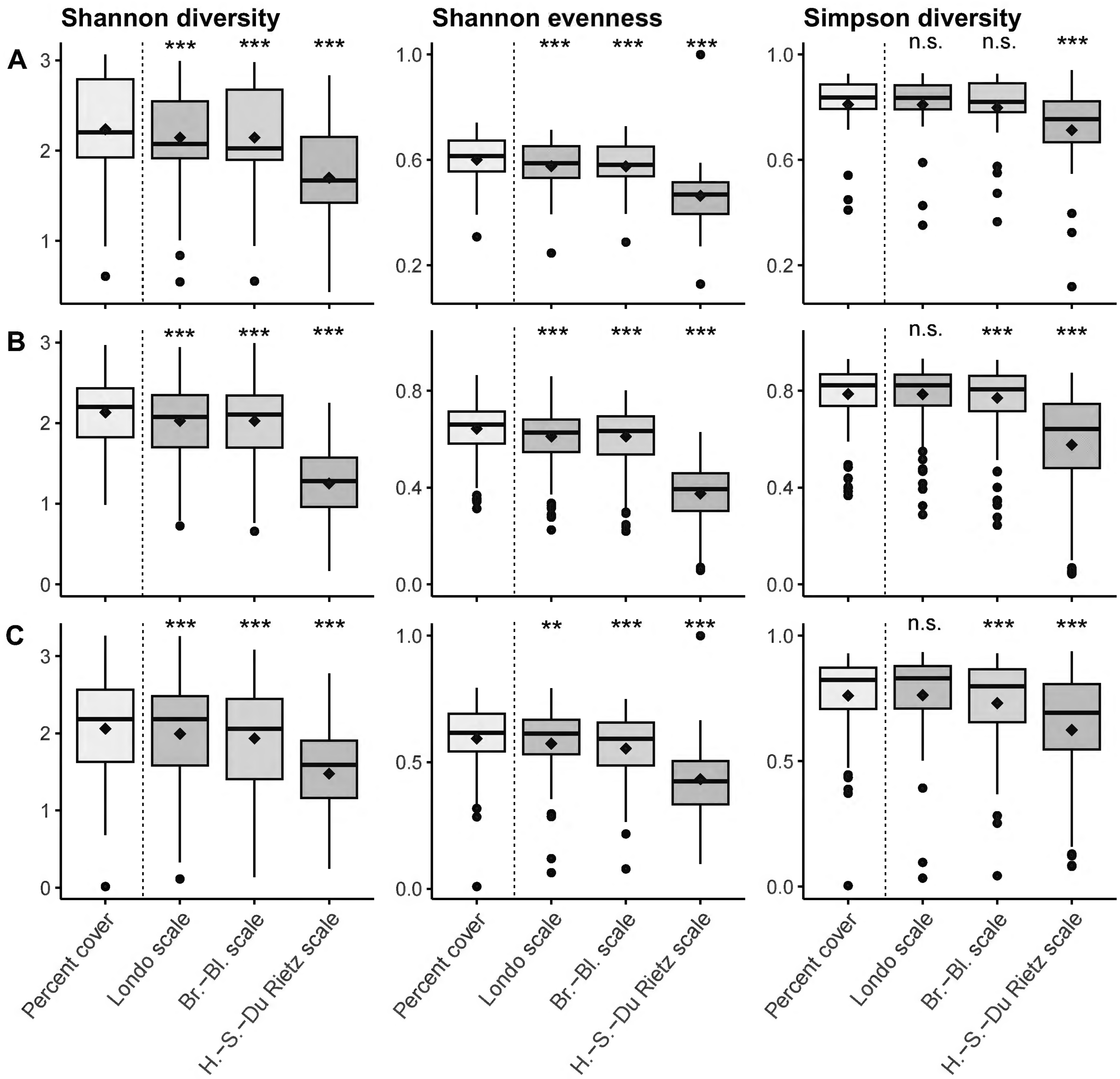


**Figure 2.** Boxplots comparing three diversity metrics across three datasets when cover values are estimated directly in percent, based on the 13-step Londo scale, a 7-step Braun-Blanquet scale, and the 5-step Hult-Sernander-Du Rietz scale. Back-translation from the ordinal scales to percent was done with the geometric means of the class borders. The rows correspond to the datasets A, B and C. The asterisks indicate the Bonferroni-corrected *p*-values from paired *t*-tests of the values achieved with the ordinal scales vs. the values on the original scale.

From the three compared ordinal scales, the Hult-Sernander-Du Rietz scale showed in all cases the most severe biases, with Shannon diversity being on average 0.96 too high for back-translation with arithmetic means and 0.67 too low in the case of geometric means (Table 3, Figures 1, 2). By contrast, the arithmetic back-translation led to moderate biases in the case of the Londo scale, while in the three other combinations (Braun-Blanquet arithmetic and geometric and Londo geometric) the biases were small and only partly significant (Table 3, Figures 1, 2). Among the three biodiversity metrics, Shannon diversity was most negatively affected and Simpson diversity least (Table 3).

Applying an ordinal transformation to percentage cover in most cases affected the diversity rank of a community in a dataset (Table 4). The patterns were similar across the three datasets and the two back-translations. Generally, the distortion was less pronounced for the 13-step Londo and 7-step Braun-Blanquet scales than for the 5-step Hult-Sernander-Du Rietz scale. The effects were similar for the three biodiversity metrics and the two approaches of back-transformation (Table 4). When standardized to 100 plots, the mean and maximum rank changes were quite similar within each combination of ordinal scale × biodiversity metric and only slightly lower for dataset A (not shown). Thus, we averaged the standardized values across the three datasets (last four rows in Table 4). Even in the least affected combination (Simpson diversity, Braun-Blanquet scale, geometric back-transformation), in a 100-plot sample there would be an average change in rank of 4.1 per plot and a maximum change of 18. In the most affected combination (Shannon evenness, Hult-Sernander-Du Rietz scale, arithmetic back-transformation) plots on average would change their rank by 22.8 positions and in the extreme case by 79 positions.

**Table 4.** Changes in biodiversity ranking due to the application of ordinal scales. The table shows the mean and maximum rank change for three diversity indices (Shannon = Shannon diversity, Evenness = Shannon evenness, Simpson = Simpson diversity) in the three test datasets (A, B, C) when the percentage cover is transformed to the 13-step Londo, 7-step Braun-Blanquet or 5-step Hult-Sernander-Du Rietz ordinal scales. The results are always given for two approaches of back-transformation from the ordinal scale, arithmetic mid-point and geometric mid-point. In the last four lines the results of the three datasets are averaged and standardized to a dataset of 100 plots.

| Dataset | *n* | Approach | Statistic | Londo vs. % cover | | | Braun-Blanquet vs. % cover | | | Hult-Sernander-Du Rietz vs. % cover | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Shannon | Evenness | Simpson | Shannon | Evenness | Simpson | Shannon | Evenness | Simpson |
| **A** | 32 | arithmetic | Mean | 2.1 | 3.6 | 2.1 | 0.9 | 1.7 | 2.4 | 4.1 | 7.4 | 4.8 |
| | | arithmetic | Max | 7 | 12 | 6 | 4 | 6 | 10 | 13 | 21 | 13 |
| | | geometric | Mean | 1.3 | 2.2 | 2.9 | 1.2 | 2.4 | 1.5 | 4.3 | 5.1 | 4.5 |
| | | geometric | Max | 6 | 9 | 8 | 5 | 9 | 6 | 23 | 13 | 17 |
| **B** | 171 | arithmetic | Mean | 9.6 | 9.4 | 7.6 | 10.6 | 13.5 | 13.8 | 24.8 | 33.6 | 24.9 |
| | | arithmetic | Max. | 52 | 55 | 34 | 50 | 71 | 74 | 101 | 126 | 116 |
| | | geometric | Mean | 10.2 | 13.8 | 14.5 | 9.1 | 11.4 | 7.8 | 31.4 | 36.7 | 30.1 |
| | | geometric | Max. | 48 | 64 | 63 | 59 | 67 | 35 | 133 | 121.5 | 138.5 |
| **C** | 60 | arithmetic | Mean | 3.3 | 5.1 | 2.4 | 3.5 | 5.7 | 4.6 | 7.1 | 15.3 | 8.2 |
| | | arithmetic | Max. | 16 | 37 | 12 | 23 | 28 | 22 | 32 | 58 | 37 |
| | | geometric | Mean | 3.2 | 5.0 | 4.2 | 2.5 | 3.8 | 1.9 | 10.3 | 12.7 | 10.7 |
| | | geometric | Max. | 18 | 22 | 20 | 12 | 18 | 9 | 54.5 | 59 | 56.5 |
| **Average** | 100 | arithmetic | Mean | 5.9 | 8.4 | 5.0 | 4.9 | 7.5 | 7.7 | 13.1 | 22.8 | 14.3 |
| | | arithmetic | Max. | 26.3 | 43.8 | 19.5 | 26.7 | 35.6 | 37.1 | 51.0 | 78.7 | 56.7 |
| | | geometric | Mean | 5.1 | 7.7 | 8.1 | 4.4 | 6.9 | 4.1 | 16.4 | 19.6 | 16.5 |
| | | geometric | Max. | 25.6 | 34.1 | 31.7 | 23.4 | 32.4 | 18.1 | 80.2 | 70.0 | 76.1 |

# Discussion

We had expected that all ordinal scales would change the three biodiversity metrics systematically, albeit to a different degree, depending on the level of resolution of the ordinal scales. Accordingly, we had hypothesized that the 5-step Hult-Sernander-Du Rietz scale would create the largest biases, followed by the 7-step Braun-Blanquet scale, while the 13-step Londo scale should be the least affected as it is more similar to a direct percent estimation. Indeed, we found that, among the three compared ordinal scales, Hult-Sernander-Du Rietz by far and consistently produced the largest biases. By contrast, there was not a systematic difference between the Braun-Blanquet and the Londo scales, except for Shannon diversity and arithmetic back-translation where contrary to our assumption Londo performed worse than Braun-Blanquet. The finding that the Braun-Blanquet scale performed similarly or even better than the Londo scale despite it is coarser (7 steps vs. 13 steps) was unexpected. This points to the fact that it is not only the overall number of steps, but the resolution among the smaller cover values that is important. Here the Braun-Blanquet variant used in the comparison benefitted from the fact that it had two steps for cover values below 1%, while the Londo scale does not differentiate below 1%.

In all cases the mean diversity metrics were higher when ordinal scales with arithmetic back-translation were applied than without, but not always significantly. This can be explained by the cover value distribution (often called species-abundance distribution; SAD; see Ulrich et al. 2022). As already highlighted by Preston (1948), in biological samples there are almost always more rare than frequent species, and the abundance distribution in species communities approximately follows a log-normal curve but with its left-most part being cut off in limited samples (like plots). Applying this knowledge to ordinal scales and their common back-translation into percent means that through this procedure more species will receive higher than lower covers after the double translation. This is simply a consequence of the typical approach (see Table 2) of back-translating the ordinal values to the arithmetic mean of the class borders (e.g. the Braun-Blanquet category "2", ranging from 5–25% cover is replaced by 15%). Usually, there will be more species between 5% and 15% than between 15% and 25%. Thus, more species will enter into the diversity calculation with a higher cover than with a lower cover than they actually had. This effectively increases the Simpson diversity index and also the Shannon diversity index except for high relative covers above $p_i \approx 0.37$ (not shown). As ordinal scales with finer resolution (more classes) come closer to the original values (have less information loss) and thus produce less bias in biodiversity metrics, we initially had assumed that the 7-step Braun-Blanquet scale would turn out to be perhaps halfway between the original data and the 5-step Hult-Sernander-Du Rietz scale. By contrast, we found it to be much closer to the original values. Again, it is not so much the overall number of categories in a scale that is important, but the resolution at the lower cover values where most of the species are recorded. Here, the category "1" of the Hult-Sernander-Du Rietz scale combines all cover values up to 6.25%, whereas in the 7-step Braun-Blanquet scale,

these lower cover values are subdivided into four categories. Replacing all cover values from 0.001% upwards with 3.125% evidently increases the calculated diversity, and with so many species falling within the same cover category necessarily the calculated evenness must be high.

Regarding the biodiversity ranking, we found effects for all three ordinal scales, three biodiversity metrics and two approaches of back-translation. The degree of distortion varied for the combinations of ordinal scale × biodiversity metric but was highly consistent across the three datasets and the two back-translation approaches. Even in the least affected combination (Braun-Blanquet, Simpson diversity, geometric back-translation) the most affected plot would change its ranking by 18 within 100. However, in the most affected combination (Hult-Sernander-Du Rietz, Shannon diversity, arithmetic back-translation) this increased to 80 within 100. This means that a plot rated among the most diverse based on the cover in the field, could be rated among the least diverse after ordinal transformation or *vice versa*. Since the typical application of biodiversity metrics is to compare communities or community types in their relative position to each other, evidently no ordinal scales should be used for sampling in such cases. It does not help if the overall mean over a large and heterogeneous dataset as in our three examples remains the same, if this results from similar numbers of plots showing strong increases and strong decreases in the biodiversity metric.

We also tested a second way of back-translating ordinal values to percent cover to see whether this would reduce the distorting effects. Based on the observation that in most cases and for most cover intervals there are more species with lower than with higher cover (see Preston 1948; Ulrich et al. 2022), we had anticipated that the geometric midpoint of the cover class borders could bring an improvement. Indeed, the patterns changed, but instead of an overestimation of biodiversity indices this led now to a consistent underestimation. Across all datasets and biodiversity metrics, the degree of underestimation with geometric mid-points was slightly lower than the degree of overestimation with arithmetic mid-points (-0.14 vs. +0.21; Table 3), suggesting that geometric mid-points could be a better generic solution. However, when focussing on the Braun-Blanquet scale, which is globally by far the most used ordinal scale (Bruelheide et al. 2019), the arithmetic approach was slightly better than the geometric approach (+0.02 vs. -0.05; Table 3), suggesting that the arithmetic approach should be retained. When looking for changes in diversity ranking, there was no clear difference between the arithmetic and geometric approach.

# Conclusion

In the first paper of the series (Dengler and Dembicz 2023) we showed that the use of ordinal scales leads to a considerable information loss, given the same sampling accuracy in the field, but we did not analyse how this potentially translates into biased results in vegetation studies. Here we explored the effects on one typical aspect of vegetation studies: biodiversity indices. We have shown that the application of ordinal scales severely affects biodiversity indices. While the mean metrics are most strongly affected in the case of the 5-step Hult-Sernander-Du Rietz scale (and mostly minimally in the 7-step Braun-Blanquet and 13-step Londo scales), all three scales severely distorted the biodiversity ranking of communities. We therefore recommend the following:

1) If comparisons of biodiversity metrics other than species richness are planned, the use of ordinal scales should be avoided in field sampling, and instead direct percent values should be estimated.
2) Our results suggest that it might be beneficial for large vegetation plot databases like the European Vegetation Archive (EVA; Chytrý et al. 2016), sPlot (Bruelheide et al. 2019) or GrassPlot (Dengler et al. 2018) to store and provide the original scale used in the field, in addition to the (partly back-transformed) harmonised percentage covers. This would allow users to account for possible distorting effects of the ordinal transformations (e.g. by filtering for plots that were sampled with percentage cover or, if including plots recorded with ordinal scales, considering a different back-translation than the arithmetic class mid-point).
3) Since our analyses did not yield a clear superiority of either the arithmetic or geometric mid-point approach for the back-translation of ordinal cover values, we recommend more comprehensive studies with a variety of back-translation approaches utilising different datasets with known percent cover values, to establish for each ordinal scale the best general back-translation.

# Data availability

The raw data are available in Suppl. material 1.

# Author contributions

JD and ID conceived the idea of this study, ID conducted the analyses, JD drafted the manuscript, which was revised by both authors.

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## Supplementary material

**Supplementary material 1**
**Datasets A, B and C used in this study with anonymised species names and species cover data (*.xlsx)**
Link: https://doi.org/10.3897/VCS.144252.suppl1

**Supplementary material 2**
**Biodiversity metrics (per plot and mean) for the three datasets A, B and C, before and after application of an ordinal scale, as absolute values, ranks, and changes in both due to the transformation (*.xlsx)**
Link: https://doi.org/10.3897/VCS.144252.suppl2